LIMESTONE ROCK FRAGMENTATION ANALYSIS USING WipFrag

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN
MINING ENGINEERING

BY

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National Institute of Technology
Rourkela

CERTIFICATE

This is to certify that the thesis entitled **"Limestone rock fragmentation analysis using WipFrag"** submitted by **Sri M.VENKATESH** in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Quick and accurate measurements of size distribution are essential for managing fragmented rock and other materials. Various fragmentation measurement techniques are available and used by industry/researchers but most of the methods are time consuming and not precise. WipFrag is an automated image based granulometry system that uses digital image analysis of rock photographs and video tape images to determine grain size distributions.

WipFrag images can be digitized from fixed video cameras in the field, or using roving camcorders. Photographic images can be digitized from slides, prints or negatives, using a desktop copy stand. Digital images in a variety of formats, delivered on disk or over electronic networks, can be used.

In course of the project, ten rock pile samples have been collected using Sony camcorder at different angles. The photographs are analyzed in a system using WipFrag image analysis software. The analyses of photographs are carried out using single image and multiple image analysis techniques. The cumulative size distribution is obtained from single image analysis technique where as multiple image analysis technique is used for optimum rock fragmentation

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CHAPTER – 1

INTRODUCTION

1.1 General

Fragmentation is the process of breaking the solid in situ rock mass into several smaller pieces capable of being excavated or moved by material handling equipment. Breakage of rock mass is assisted by conventional drilling blasting operation which is the most important method of fragmentation in almost every quarry. There are a number of controllable as well as uncontrollable parameters that govern the fragmentation of rock. The controllable parameters can be controlled by effective blast designing and use of appropriate explosive for blasting. While the uncontrollable parameters as the name suggests cannot be controlled. But certain measures have to be taken to minimize the effects of these parameters in rock blasting in order to attain an optimum rock fragmentation (Raina et al., 2002).

1.2 **Optimum rock fragmentation** (Mohanty et al., 1996)

The rock fragmentation obtained as an outcome of blasting operations is said to be optimum, when it contains maximum percentage of fragments in the desired range of size. The Desired size usually means the size that is demanded and can be effectively utilized by the consumers for further operations devoid of any processing. The desired size for different consumers is different. For example, the size of dolomite fragments required for railway tracks is comparatively smaller than the coarser ones those used by a cement industry.

1.3 **Significance of optimum rock fragmentation** (Hartman et al., 1992)

The significance of optimum rock fragmentation is, to fulfill the varying demands of different consumers for assorted sizes of rock fragments, to reduce the cost of crushing and grinding or palletization operations, and finally uphold the economics of mining. For this the rock must be fragmented in such a way that further processing (usually termed as Milling) is not required. In other words, if the cost per ton of broken ore is greater than the price it commands when sold as the final product, then the production is not considered to be economic. Hence the cost of milling should be minimized and it should be ensured that the primary blast results in optimum fragmentation.

1.4 Achievement of optimum rock fragmentation (Hartman et al., 1992)

To achieve an optimum rock fragmentation a blast with optimized controllable parameters should be designed so that the effects of the uncontrollable parameters could be minimized. The controllable parameters for optimum fragmentation can be fixed after conduction of trial blasts in a mine and quantification of fragmentation. Quantification of fragmentation refers to the measurement of fragmentation in order to predict the necessary corrections in the blast design. These corrections when applied to the blast design results in almost acceptable fragmentation.

1.5 Objectives of the work

The objectives of the project are as follows:

- To study the WipFrag image analysis software.
- To analyze the fragmentation characteristics of the blasted muck of a limestone mine using the WipFrag image analysis system.
- To obtain the optimum size distribution of the sample.

CHAPTER – 2

LITERATURE REVIEW

2.1 Fragmentation measurement techniques

Blast optimization requires a degree of compromise between the competing objectives of maximum fragmentation, minimum dilution and minimum costs for drilling and explosives. Also, mining companies and quarry operations have to examine and reduce production costs to remain competitive. But no single factor, such as cost of explosives, can be properly evaluated without measurements of fragmentation and rock quality. Hence the need to manage production costs necessitates the need to measure the post-blast fragmentation.

Quantification of fragmentation on a larger scale is an extremely complicated task. Because it needs a substantial amount of time to find out manually the grain size distribution in a muckpile. Research has been carried out worldwide with different methods and tools for measurement of fragmentation. These methods are listed below.

- Sieving or Screening.
- Oversize boulder count method.
- Explosive consumption in secondary blasting method.
- Shovel loading rate method.
- Bridging delays at the crusher method.
- Visual analysis method.
- Photographic or manual analysis method.
- Conventional and high speed photogrammetric method.
- High speed photography or image analysis method.

2.1.1 Sieving or screening (Hinton et al., 2006)

Sieving or screening is a direct and accurate method of evaluation of size distribution of particles or fragmentation. However, for production blasting, this method is costly, time-consuming and inconvenient. This method is feasible in case of small scale blasts. In this method the rock fragments are screened through sieves of different mesh numbers for different fragment sizes. Then the screened out fragments are grouped according to their size and the number of fragments in each size range is counted to predict the nature of the blast.

2.1.2 Oversize boulder count method (Holmberg et al., 2000)

In Oversize boulder count method, manual counting of the oversize boulders in the muck pile which cannot be handled by the shovel is done. This directly gives an over-size index with respect to the total in-situ rock mass blasted. It is a very popular method of determining the post-blast fragmentation.

2.1.3 Explosive consumption in secondary blasting method (Melnikov et al., 1978)

In Explosive consumption in secondary blasting method, an index regarding the consumption of explosives in secondary blasting by either pop shooting or plaster shooting is determined. This index is then used for comparing the degree of fragmentation of a group of blasts.

2.1.4 Shovel loading rate method (Monjezi et al., 2009)

The shovel loading rate method assumes that the faster the mucking the better the fragmentation. In this method the loading rate of shovel for a particular muck pile is taken in to account. This technique may be used more accurately for a comparative account of the nature of fragmentation of a group of blasts.

2.1.5 Bridging delays at the crusher method (Jimeno et al., 1995)

In the Bridging delays at the crusher method, the delay in bridging at the crusher mainly due to oversize boulders is observed. This attributes in determining the number of oversize boulders in the muck pile. This method is usually preferable in a small production site rather than in large scale blasting situations.

2.1.6 **Visual analysis method** (Maerz et al., 1996)

The Visual analysis method is a subjective assessment method. In this method the post-blast muck is viewed immediately after blasting and a subjective assessment is made. This technique is not dependable as the superficial view of the muck cannot enlighten anything about the hidden portion.

2.1.7 **Photographic or manual analysis method** (Sudhakar et al., 2005)

In photographic method delineating of fragments on the photographs of muck pile is carried out manually to determine the number of fragments using a graph paper. For this, 0.15m x 0.10m size photographs of the muck pile are printed. Each photograph is then placed under a transparent paper by fixing it firmly with the help of pins. All the fragments are delineated on the transparent paper. Delineation is started with large fragments because they have more effect on the results. It is tried to detect and delineate fragments as small as possible. The scale placed in the middle of the muck pile is used to convert the measured distance on the photograph to actual distance. Then, a Xerox copy of the traced paper is placed on a graph paper. The area of the reference scale on graph paper is noted down and then a scale factor (actual area of scale/graph area of scale) is determined. For every identifiable fragment, the area covered by the fragment is measured by counting the number of small blocks on the graph paper covered by that fragment. The area is then multiplied with the scale factor. For converting the area into volume, the third dimension is determined using the method of equivalent circle of area. The parameters are calculated as follows:

Equivalent diameter = $\sqrt{(4 \times \text{Area}/\pi)}$, m
Spherical volume = Area x Equivalent diameter, m3
Weight of the fragment = Spherical volume x density of the rock, kg

The manual analysis of each photograph takes about one to two hours.

2.1.8 Conventional and high speed photogrammetric method (Wallace et al., 2006)

This method is more reliable and accurate than the photographic method. It can provide three dimensional measurements and thereby helps in the calculation of fragmentation volume.

2.1.9 High speed photography or image analysis method (Maerz et al., 1996)

Nowadays High speed photography or Digital images processing and analysis systems emerged with the advance in technology are becoming increasingly popular in fragmentation measurement. This is due to their advantages over photographic methods. Consequently several countries and organizations have developed their own image analysis systems. Some of these systems include:

- **IPACS**
- **TUCIPS**
- **FRAGSCAN**
- **SPLIT**
- **Fragalyst**
- **WipFrag**

2.1.9.1 IPACS (Dahlhielm et al., 1996)

The IPACS consists of grabbing, scaling, image enhancing, grey level image segmentation, shape analysis (merging and splitting) and processing parameters as the software functions. The host computer required for this image analysis system is an industrial PC. Therefore this system is well suited for industrial purposes. The Processing speed and accuracy of IPACS are good, and the system is conducted automatically with a video input picture.

2.1.9.2 TUCIPS (Havermann et al., 1996)

The TUCIPS has been developed to measure blast fragmentation at Technical University Clausthal (Germany). This system involves general algorithms of image processing and a specially created algorithm for muckpile image analysis. This system is suitable for practical use because there is just five percent (5%) deviation in the practical test with this program.

2.1.9.3 **FRAGSCAN** (Schleifer et al., 1996)

The FRAGSCAN uses the method of measurement of the size distribution of blasted rock from dumper or conveyer belt with the help of a camera and mathematic morphology technique. The FRAGSCAN equipment is composed of a camera, an Image acquisition card, a control data card, computer type PC and a light. Conversion from surface to volume distribution is made possible by using a spherical model. This operating system is fully automatic tool and provides reliable as well as consistent results because extensive experimentation has provided satisfying results. This system is better for industrial usage.

2.1.9.4 **SPLIT (**Higgins et al., 1999**)**

The SPLIT is image analysis software developed by the University of Arizona to figure out size distribution of rock fragment. It is operated with eight bit grayscale images of rock fragments. There are two kinds of SPLIT programs; one is an automatic and continuous program that is used on the conveyor belt and the other is a manual program which uses the saved images. However, the same algorithm is used in both programs. A digital camera is used to get the image of the bench face, which is to be used in SPLIT. The maximum size of image that can be processed using SPLIT is 1680 x 1400 pixels, so the maximum size of image needs to be considered during sampling images because image editing may be required in SPLIT, and a larger image may not be opened in SPLIT without such editing.

Image samples are obtained during charging the blast holes. Approximately five to seven (5-7) pictures are taken at each blasting, and three to five (3-5) appropriate pictures for analyzing in SPLIT are chosen. The digital camera should be held such that the long axis of the photograph is vertical. The image should be taken with the camera lens perpendicular to the muck pile surface. An article of known dimensions must be in the picture in order to provide scale. A white fig may be used as a scale material on the bench face. The same scale material must be used from image to image for analyzing all pictures in SPLIT regarding each blasting. Also, the number of scale materials should be the same from image to image for analysis. Fragmentation assessment is achieved by analyzing the scaled photographs of the muck pile.

2.1.9.5 **Fragalyst** (Raina et al., 2002)

The Fragalyst is an image analysis system developed by CMRI Regional Centre, Nagpur (India) and Wavelet Group of Pune (India). This system consists of capturing video photographs of the muck pile, down loading the photographs to the computer, or capturing the photos of muck pile from field by digital camera/ordinary camera then converting the images to grey scale, image enhancement, calibration and blob (grain) analysis. With the aid of menu-driven software, it is possible to determine the area, size and shape of the fragments in a muck pile/grain aggregates on the basis of grey scale difference. The 2-D information available from software can further be processed for stereological analysis for 3-D information.

2.1.9.6 **WipFrag** (Maerz et al., 1996)

The WipFrag image analysis software uses the technique of analysis of digital image of the blasted rock with granulometry system to predict the grain size distribution in the muck pile. Typically, camcorder images of the muck pile are acquired in the field. A scale device is used in each view to reference the sizing. The muck pile is photographed or videotaped and this image is transferred to the WipFrag system. The broken rock image is transformed into a particle map or network. Network areas are converted into volumes and weights and the resulting data is displayed as a graph. The fidelity and speed of fragment edge detection allow fully automatic remote monitoring at a rate of one image per 3 to 5 seconds. More fragments are resolved, over a greater size range.

WipFrag allows comparing the automatically generated net against the rock image. The fragment boundaries are analyzed efficiently using Edge Detection Variables (EDV). Any inaccuracies can be corrected by manual editing with a mouse to improve edge detection. Manual editing, however, is needed only if image quality is poor and is simplified by a "smart edit" function that erases and draws lines, linking them automatically to the existing fragment net.

CHAPTER – 3

WipFrag

3.1 Introduction

The WipFrag image analysis software is recently developed granulometry software (Maerz et al., 1996). It utilizes the technique of measurement of fragmentation with the help of digital images of blasted muck pile. Usually camcorder images of the muck pile are captured in the field. A Cannon or Sony Hi-8 video camcorder is offered as a standard for this purpose. These images are then transferred to the WipFrag system. The WipFrag system consist a software pack installed in a Pentium computer equipped with additional RAM memory, mouse, monitor and a suitable operating system. A hard lock key is provided with the WipFrag software pack as security equipment which has to be inserted in the CPU to run the software. The images of the muck pile transferred to the WipFrag system are analyzed by delineating the fragment edges with automatic netting followed by manual editing. These Network areas are converted into volumes and weights and the resulting data is displayed as a graph. The detailed methodology of fragmentation analysis with a WipFrag system is discussed in further sections.

3.2 Rock pile sampling and Photography (Franklin et al., 1996)

Rock pile sampling refers to the process of collection of the blasted muck pile samples in the form of digital images by capturing photographs. The basic underlying rule in sampling is that the larger the number of images processed, the more reliable the results. This is due to the non-homogeneous nature of muck pile and the greater statistical sampling base. Rock sampling is a complex process involving following steps –

- Selection of suitable viewpoints from where the most representative rock pile samples can be collected. Since we can only measure what we can see, so to obtain reliable results of the fragmentation analysis some precautions have to be taken during selecting viewpoints.

- At least one scaling object of known length such as a 2 m white scale bar or staff has to be positioned near the edge of the muck pile so as not to obscure the rock we are trying to measure.
- A suitable camcorder is then set in front of the muck pile and several shots are taken. Preferably at least five shots are taken at random locations for a large rock pile. For improved estimates of oversize the number of full scale shots should be increased to at least ten.

3.2.1 Precautions

Following precautions have to be taken during photography –

- Avoid wide-angle close-up photography and oblique shots that distort the scale. If the rock pile surface is oblique to the camera, place identical scaling object at the nearest and the furthest points that can be averaged or used in auto-tilt correction.
- Since the WipFrag detects the rock edges depending on the intensity of light, provide uniform indirect or diffusing light without excessive sharp or one-sided shadows and "hot spots" for photography. WipFrag works best when each fragment is equally bright and surrounded by a thin, uniform shadow.
- Choose dull days in preference to bright sunlight for photography.
- Beware of rock pile segregation. Large blocks tend to roll to the outer edges and fines may cover the surface or become hidden as a result of gravity or rainfall. The effects can be minimized by increasing the number of images per sample but only with careful selection of image locations.
- Maintain the camera in good working condition and protect it from dust and mechanical damage.

3.3 Methodology

Methodology are discussed in the following steps:-

3.3.1 Transferring the digital images to the WipFrag system

The images of the muckpile captured during rock pile sampling are uploaded into the WipFrag system through a suitable data cable. This data cable connects the camcorder directly to the CPU. The images are saved in the computer hard disk drive as bitmap (.bmp) or jpeg (.jpg) files.

3.3.2 Opening an image in the WipFrag window for analysis

For opening an image of the blasted muckpile in the WipFrag window, the File menu is opened and 'OPEN' option is clicked on. This command opens a dialogue box from where a photograph may be selected and opened.

3.3.3 Set tilt option

After opening a muck pile photograph on the WipFrag window, the tilt correction is done. For obtaining precise results, it is necessary during photography that the horizontal axis of the camera should be normal to the surface of the muck pile. But this is practically impossible to keep the horizontal axis normal to the inclined face of the muck pile. Hence the images are captured from the viewpoint exactly in front of the muck pile with the horizontal axis of the camera at some angle to the face of the muck pile.

For capturing images of the muck pile in such a manner, the use of a scaling object becomes necessary. Two white scale bars or staffs of known length are suitable for this purpose. One of the two bars is placed at the top edge of the muck pile while the other is placed at the bottom edge. The image captured with the help of these bars will be adequate for tilt correction during analysis. Hence before we start the analysis of the rock pile sample we have to set the tilt of the muckpile profile. This can be done by clicking on the 'Set tilt' option in the 'Fragmentation' menu.

3.3.4 Edge detection settings

After the tilt scaling the most important operation to be performed is the Edge detection settings. The edge detection settings include the settings of a set of certain parameters called the edge detection parameters. Edge detection parameters are the numerical values used by the WipFrag during the various stages of fragment edge detection. To perform the edge detection settings the option 'Edge detection parameters' in the 'Options' menu is clicked on. This command opens a dialogue box .The ‘Default’ settings shown in the dialogue box are recommended for normal operation with good image quality as shown in Table 3.1.

TABLE 3.1. Typical settings of edge detection parameters

EDGE DETECTION PARAMETERS	DEFAULT SETTINGS	TOM’S PICK	PRESET 5	RANGE
Window size	50	125	70	30 to 110
Threshold	-9	-5.0	5	-15 to +25
Valley Threshold	-1.0	-2.0	-2.0	-4.0 to 0
Search length 1	24	15	25	5 to 40
Search length 2	16	12	15	5 to 40
Search length 3	12	8	10	5 to 40

3.2.5 Generating net

Net generation refers to the process of generating the overlay network of block outlines. These outlines delineate the edges of the fragments. The option for generating the net appears as we click on the ‘Fragmentation’ menu

On pressing the ‘Generate net’ option the automatic edge detection automatically runs through a series of edge detection operation to obtain a net of lines corresponding closely to fragment boundaries. This process typically takes a few seconds and for this tenure the WipFrag displays a status window showing the progress status of auto netting.

3.2.6 WipFrag Output

The output of the granulometry analysis with the WipFrag software essentially consists of a cumulative size table either in ISO or US standard sieve sizes whichever has been selected during sieve default settings.

CHAPTER – 4

RESULTS AND ANALYSIS

In course of the project, ten rock pile samples have been collected using Sony camcorder at different angles. The photographs are analyzed in a system using WipFrag image analysis software. The analyses of photographs are carried out using single image and multiple image analysis techniques. The cumulative size distribution is obtained from single image analysis technique where as multiple image analysis technique is used for optimum rock fragmentation

After following methodology on rock pile sample1 to sample10, the results of the individual sample1 to sample10 using WipFrag single image analysis are shown in corresponding sample photographs. Single image analysis will provide only the cumulative rock size using WipFrag

4.1 Single image analysis using WipFrag

Using WipFrag image analysis software the photographs of rock pile sample 1 to 10 are analyzed and the results are listed in the following plates. The cumulative size obtained by individual photographs will not provide any optimum rock size fragmentation, so to obtain optimum rock size fragmentation all the ten photographs are merged and analyzed in WipFrag using multiple image analysis technique and the results are listed in TABLE 4.1 and TABLE 4.2

PLATE 4.1. Photograph of rock pile sample 1

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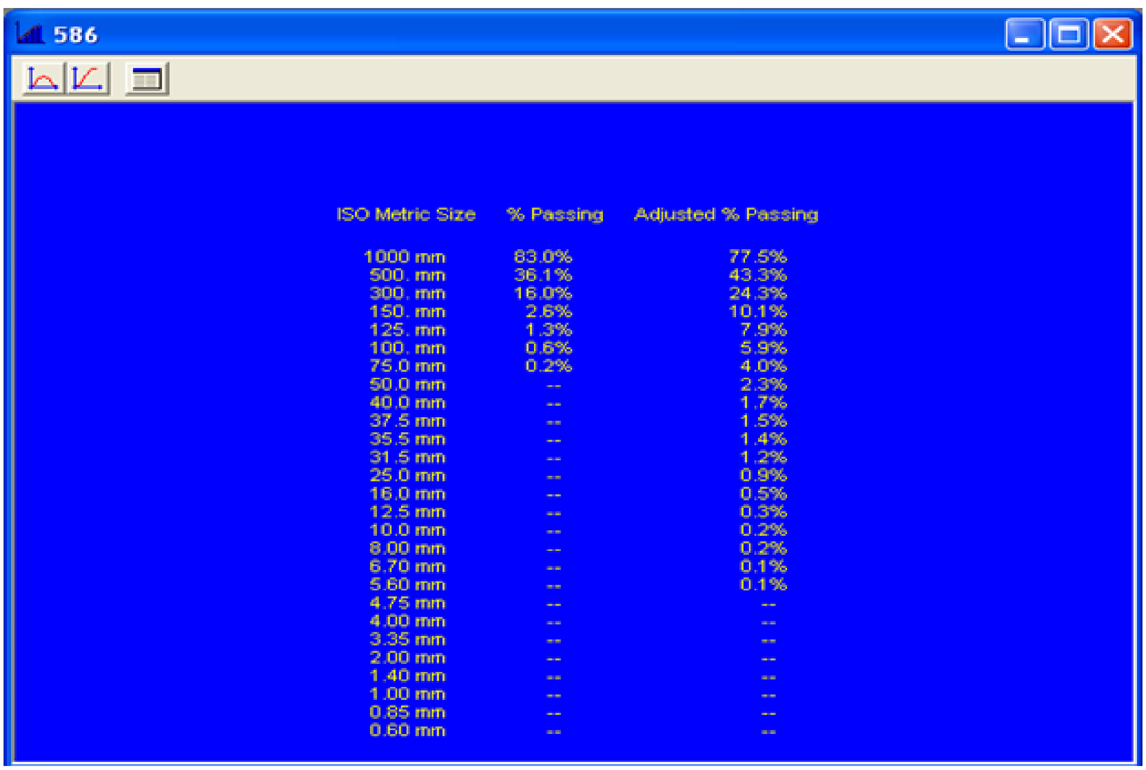
ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	100.0%	90.5%
500. mm	50.2%	54.1%
300. mm	18.7%	29.1%
150. mm	2.9%	10.8%
125. mm	1.6%	8.2%
100. mm	0.7%	5.8%
75.0 mm	0.2%	3.7%
50.0 mm	--	2.0%
40.0 mm	--	1.4%
37.5 mm	--	1.2%
35.5 mm	--	1.1%
31.5 mm	--	0.9%
25.0 mm	--	0.7%
16.0 mm	--	0.3%
12.5 mm	--	0.2%
10.0 mm	--	0.2%
8.00 mm	--	0.1%
6.70 mm	--	--
5.60 mm	--	--
4.75 mm	--	--
4.00 mm	--	--
3.35 mm	--	--
2.00 mm	--	--
1.40 mm	--	--
1.00 mm	--	--
0.85 mm	--	--
0.60 mm	--	--

PLATE4. 2. Cumulative size table obtained from the analysis of sample 1

PLATE 4.3. Photograph of rock pile sample 2



586

ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	83.0%	77.5%
500. mm	36.1%	43.3%
300. mm	16.0%	24.3%
150. mm	2.6%	10.1%
125. mm	1.3%	7.9%
100. mm	0.6%	5.9%
75.0 mm	0.2%	4.0%
50.0 mm	--	2.3%
40.0 mm	--	1.7%
37.5 mm	--	1.5%
35.5 mm	--	1.4%
31.5 mm	--	1.2%
25.0 mm	--	0.9%
16.0 mm	--	0.5%
12.5 mm	--	0.3%
10.0 mm	--	0.2%
8.00 mm	--	0.2%
6.70 mm	--	0.1%
5.60 mm	--	0.1%
4.75 mm	--	--
4.00 mm	--	--
3.35 mm	--	--
2.00 mm	--	--
1.40 mm	--	--
1.00 mm	--	--
0.85 mm	--	--
0.60 mm	--	--

PLATE 4.4. Cumulative size table obtained from the analysis of sample 2

PLATE 4.5. Photograph of rock pile sample 3

592

ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	78.1%	77.2%
500. mm	36.6%	44.0%
300. mm	13.5%	25.2%
150. mm	1.6%	10.8%
125. mm	0.8%	8.5%
100. mm	0.4%	6.4%
75.0 mm	0.1%	4.4%
50.0 mm	--	2.5%
40.0 mm	--	1.9%
37.5 mm	--	1.7%
35.5 mm	--	1.6%
31.5 mm	--	1.4%
25.0 mm	--	1.0%
16.0 mm	--	0.6%
12.5 mm	--	0.4%
10.0 mm	--	0.3%
8.00 mm	--	0.2%
6.70 mm	--	0.2%
5.60 mm	--	0.1%
4.75 mm	--	0.1%
4.00 mm	--	--
3.35 mm	--	--
2.00 mm	--	--
1.40 mm	--	--
1.00 mm	--	--
0.85 mm	--	--
0.60 mm	--	--

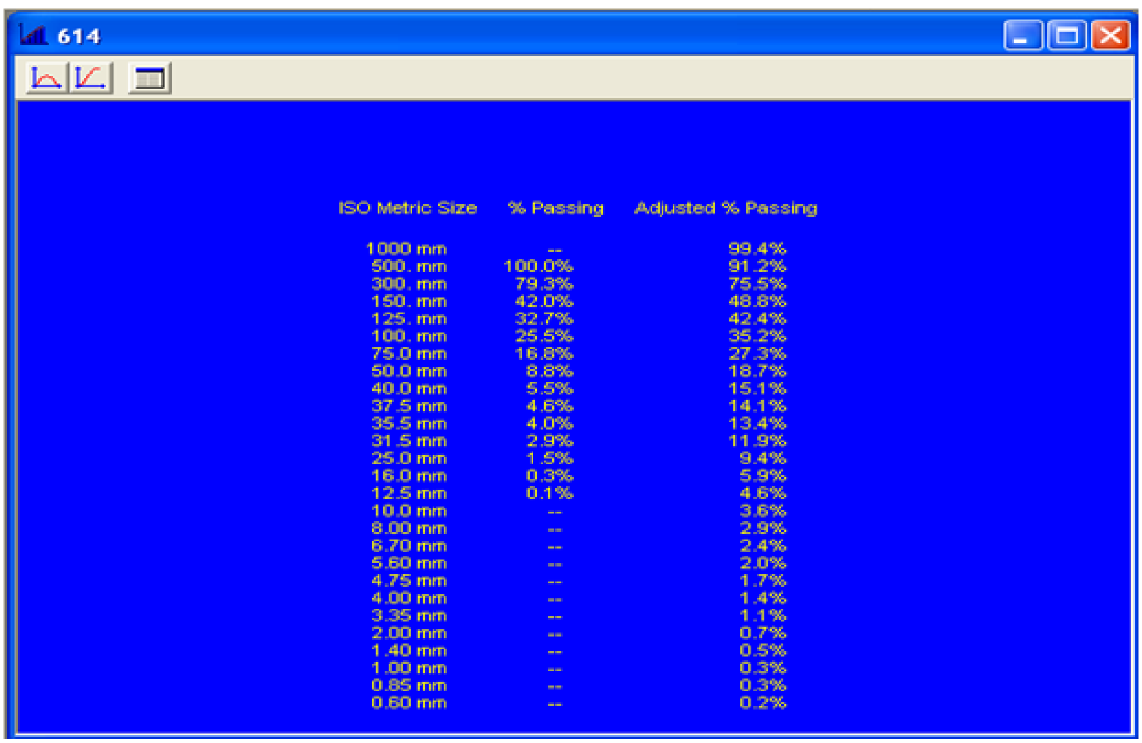
PLATE 4.6. Cumulative size table obtained from the analysis of sample 3

PLATE 4.7. Photograph of rock pile sample 4

ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	100.0%	99.8%
500. mm	94.6%	89.2%
300. mm	65.1%	64.4%
150. mm	23.0%	30.6%
125. mm	15.7%	24.2%
100. mm	10.3%	18.0%
75.0 mm	4.8%	12.1%
50.0 mm	1.2%	6.8%
40.0 mm	0.5%	4.9%
37.5 mm	0.4%	4.5%
35.5 mm	0.3%	4.1%
31.5 mm	0.2%	3.4%
25.0 mm	0.1%	2.4%
16.0 mm	--	1.3%
12.5 mm	--	0.9%
10.0 mm	--	0.6%
8.00 mm	--	0.4%
6.70 mm	--	0.3%
5.60 mm	--	0.3%
4.75 mm	--	0.2%
4.00 mm	--	0.2%
3.35 mm	--	0.1%
2.00 mm	--	--
1.40 mm	--	--
1.00 mm	--	--
0.85 mm	--	--
0.60 mm	--	--

PLATE 4.8. Cumulative size table obtained from the analysis of sample 4

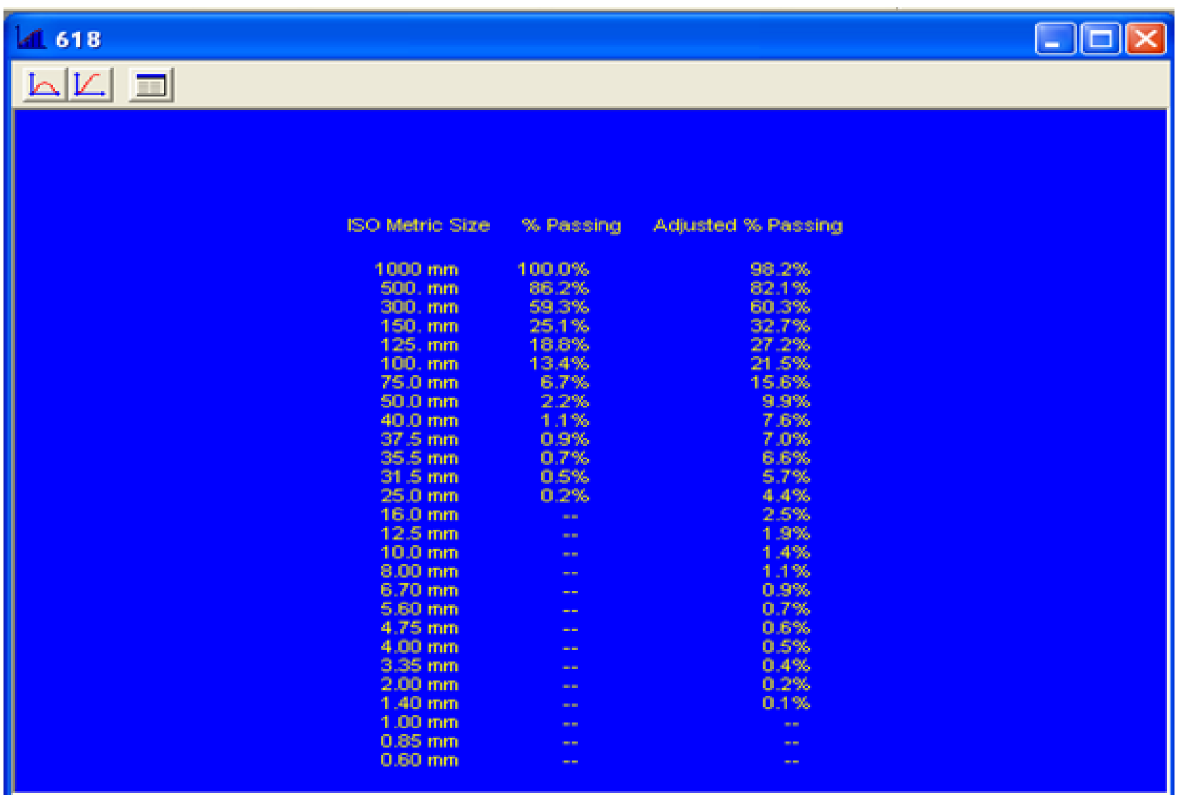
PLATE 4.9. Photograph of rock pile sample 5



ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	--	99.4%
500. mm	100.0%	91.2%
300. mm	79.3%	75.5%
150. mm	42.0%	48.8%
125. mm	32.7%	42.4%
100. mm	25.5%	35.2%
75.0 mm	16.8%	27.3%
50.0 mm	8.8%	18.7%
40.0 mm	5.5%	15.1%
37.5 mm	4.6%	14.1%
35.5 mm	4.0%	13.4%
31.5 mm	2.9%	11.9%
25.0 mm	1.5%	9.4%
16.0 mm	0.3%	5.9%
12.5 mm	0.1%	4.6%
10.0 mm	--	3.6%
8.00 mm	--	2.9%
6.70 mm	--	2.4%
5.60 mm	--	2.0%
4.75 mm	--	1.7%
4.00 mm	--	1.4%
3.35 mm	--	1.1%
2.00 mm	--	0.7%
1.40 mm	--	0.5%
1.00 mm	--	0.3%
0.85 mm	--	0.3%
0.60 mm	--	0.2%

PLATE 4. 10. Cumulative size table obtained from the analysis of sample 5

PLATE 4.11. Photograph of rock pile sample 6



618

ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	100.0%	98.2%
500. mm	86.2%	82.1%
300. mm	59.3%	60.3%
150. mm	25.1%	32.7%
125. mm	18.8%	27.2%
100. mm	13.4%	21.5%
75.0 mm	6.7%	15.6%
50.0 mm	2.2%	9.9%
40.0 mm	1.1%	7.6%
37.5 mm	0.9%	7.0%
35.5 mm	0.7%	6.6%
31.5 mm	0.5%	5.7%
25.0 mm	0.2%	4.4%
16.0 mm	--	2.5%
12.5 mm	--	1.9%
10.0 mm	--	1.4%
8.00 mm	--	1.1%
6.70 mm	--	0.9%
5.60 mm	--	0.7%
4.75 mm	--	0.6%
4.00 mm	--	0.5%
3.35 mm	--	0.4%
2.00 mm	--	0.2%
1.40 mm	--	0.1%
1.00 mm	--	--
0.85 mm	--	--
0.60 mm	--	--

PLATE 4.12. Cumulative size table obtained from the analysis of sample 6

PLATE 4.13. Photograph of rock pile sample 7

624

ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	93.6%	87.3%
500. mm	53.4%	56.3%
300. mm	28.7%	34.5%
150. mm	6.3%	15.6%
125. mm	3.7%	12.5%
100. mm	1.9%	9.5%
75.0 mm	0.7%	6.6%
50.0 mm	0.2%	3.9%
40.0 mm	--	2.9%
37.5 mm	--	2.7%
35.5 mm	--	2.5%
31.5 mm	--	2.2%
25.0 mm	--	1.6%
16.0 mm	--	0.9%
12.5 mm	--	0.6%
10.0 mm	--	0.5%
8.00 mm	--	0.4%
6.70 mm	--	0.3%
5.60 mm	--	0.2%
4.75 mm	--	0.2%
4.00 mm	--	0.1%
3.35 mm	--	0.1%
2.00 mm	--	--
1.40 mm	--	--
1.00 mm	--	--
0.85 mm	--	--
0.60 mm	--	--

PLATE 4.14. Cumulative size table obtained from the analysis of sample 7

PLATE 4.15. Photograph of rock pile sample 8

629

ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	--	100.0%
500. mm	100.0%	97.1%
300. mm	81.7%	80.1%
150. mm	37.3%	42.5%
125. mm	26.8%	34.1%
100. mm	16.2%	25.6%
75.0 mm	8.1%	17.3%
50.0 mm	1.9%	9.6%
40.0 mm	0.8%	6.9%
37.5 mm	0.5%	6.3%
35.5 mm	0.3%	5.8%
31.5 mm	0.2%	4.8%
25.0 mm	--	3.4%
16.0 mm	--	1.7%
12.5 mm	--	1.2%
10.0 mm	--	0.8%
8.00 mm	--	0.6%
6.70 mm	--	0.5%
5.60 mm	--	0.3%
4.75 mm	--	0.3%
4.00 mm	--	0.2%
3.35 mm	--	0.2%
2.00 mm	--	--
1.40 mm	--	--
1.00 mm	--	--
0.85 mm	--	--
0.60 mm	--	--

PLATE 4.16. Cumulative size table obtained from the analysis of sample 8

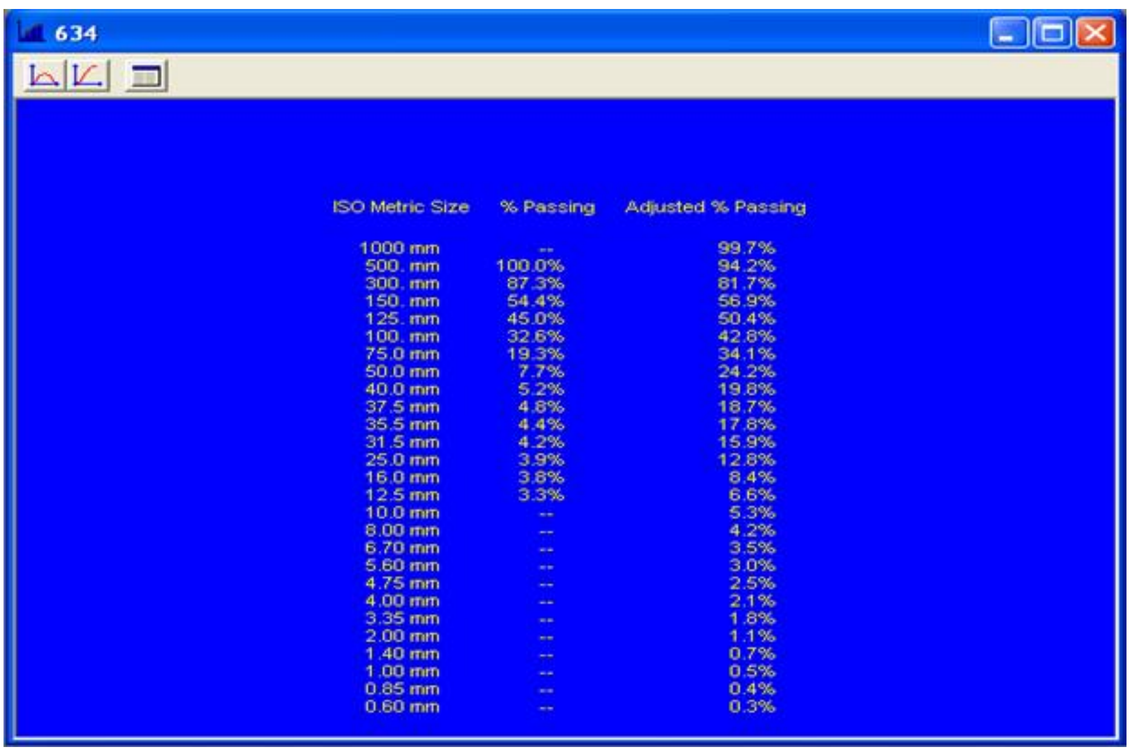
PLATE 4.17. Photograph of rock pile sample 9

631

ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	100.0%	100.0%
500. mm	97.5%	98.8%
300. mm	94.2%	94.0%
150. mm	81.4%	78.5%
125. mm	75.7%	73.0%
100. mm	67.3%	66.0%
75.0 mm	54.4%	56.7%
50.0 mm	35.1%	44.4%
40.0 mm	24.4%	38.3%
37.5 mm	21.5%	36.6%
35.5 mm	19.2%	35.3%
31.5 mm	14.8%	32.4%
25.0 mm	8.4%	27.4%
16.0 mm	2.8%	19.5%
12.5 mm	1.8%	16.0%
10.0 mm	0.1%	13.4%
8.00 mm	--	11.1%
6.70 mm	--	9.6%
5.60 mm	--	8.3%
4.75 mm	--	7.2%
4.00 mm	--	6.2%
3.35 mm	--	5.4%
2.00 mm	--	3.4%
1.40 mm	--	2.5%
1.00 mm	--	1.9%
0.85 mm	--	1.6%
0.60 mm	--	1.2%

PLATE 4.18. Cumulative size table obtained from the analysis of sample 9

PLATE 4.19. Photograph of rock pile sample 10



634

ISO Metric Size	% Passing	Adjusted % Passing
1000 mm	--	99.7%
500. mm	100.0%	94.2%
300. mm	87.3%	81.7%
150. mm	54.4%	56.9%
125. mm	45.0%	50.4%
100. mm	32.6%	42.8%
75.0 mm	19.3%	34.1%
50.0 mm	7.7%	24.2%
40.0 mm	5.2%	19.8%
37.5 mm	4.8%	18.7%
35.5 mm	4.4%	17.8%
31.5 mm	4.2%	15.9%
25.0 mm	3.9%	12.8%
16.0 mm	3.8%	8.4%
12.5 mm	3.3%	6.6%
10.0 mm	--	5.3%
8.00 mm	--	4.2%
6.70 mm	--	3.5%
5.60 mm	--	3.0%
4.75 mm	--	2.5%
4.00 mm	--	2.1%
3.35 mm	--	1.8%
2.00 mm	--	1.1%
1.40 mm	--	0.7%
1.00 mm	--	0.5%
0.85 mm	--	0.4%
0.60 mm	--	0.3%

PLATE 4.20. Cumulative size table obtained from the analysis of sample 10

The size distribution results obtained from the individual analysis of the rock pile samples are tabulated below.

TABLE4.1. Size distribution using single image analysis

	Size distribution (%)			
Sample No.	**>1000mm**	**500-1000mm**	**100-500mm**	**<100mm**
1	9.5	36.4	48.3	5.8
2	22.5	20.8	37.4	5.9
3	22.8	33.2	37.6	6.4
4	0.2	10.6	71.2	18.0
5	0.6	8.2	56.0	35.2
6	1.8	16.1	60.6	21.5
7	12.7	31.0	46.8	9.5
8	0	2.9	71.5	25.6
9	0	1.2	32.8	66.0
10	0.3	5.5	51.4	42.8

4.2 Multiple image analysis using WipFrag

The results obtained from the individual analysis of the rock pile samples cannot be treated as perfect because the digital images used for analysis cannot reveal the conditions of fragmentation behind the muck pile surface. Hence, it becomes necessary to obtain an average result of the analysis carried out with various samples. For this purpose merging of the individual results is done. The results thus obtained would be precise enough to predict the optimum blast parameters.

The results obtained from multiple image analysis are shown below

TABLE4.2. Size distribution using multiple image analysis

Multiple image analysis results	**Size distribution in (%)**			
	>1000mm	**500-1000mm**	**100-500mm**	**<100mm**
	21.2	23.5	39.2	16.1

CHAPTER – 5

CONCLUSIONS

Conclusions of the project using WipFrag image analysis software are as follows:-

- The WipFrag is efficient fragmentation analysis software and it is a direct method of fragmentation assessment as compared to the other methods such as the shovel loading rate method and the explosive consumption in secondary blasting method.
- WipFrag is a quick and time saving assessment technique.
- It possesses a high degree of accuracy and precision
- Optimum size distribution of the ten samples are analyzed with multiple image analysis WipFrag software and found that above 1000mm- 21.2 %, between 500-1000mm-23.5%, 100-500mm-39.2% and below 100mm-16.1% rocks.
- Multiple image analysis technique is better for optimum rock size distribution than single image analysis WipFrag software.

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